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# Aestivation responses of three populations of the giant African snail, *Achatina achatina* Linne (Gastropoda: Achatinidae)

## Respuestas a la estivación de tres poblaciones del caracol gigante africano *Achatina achatina* Linne (Gastropoda: Achatinidae)

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ABSTRACT

The rates of aestivation and emergence from aestivation of three experimental populations of the giant African snails *Achatina achatina* (Linne, 1758) were compared. The snails were from three origins: Donyina in the Ashanti Region, Nkasem in the Brong Ahafo Region and Apedwa in the Eastern Region of Ghana. The shortest aestivation period (4 weeks) was recorded for the Apedwa snails while the longest period (16 weeks) was recorded for the Donyina population. Data for pre-aestivation and post-aestivation growth rates show a decreasing order: Apedwa > Nkasem > Donyina. The mean growth rates eight weeks before aestivation were 3.6 g, 14.3 g and 19.2 g for the Donyina, Nkasem and Apedwa snails respectively and differed significantly (P = 0.001). The variability in growth rates and duration of aestivation reflects the optimal sizes of the natural population of the three groups.

RESUMEN

Se comparan las tasas de estivación y de abandono de la misma de tres poblaciones experimentales del caracol gigante africano *Achatina achatina* (Linné, 1758). Los caracoles eran de tres localidades diferentes: Donyina, en la región de Ashanti; Nkasem, en la región de Brong Ahafo, y Apedwa, al Este de Ghana. El periodo de estivación más corto (4 semanas) se registró en la población de Apedwa, mientras que el periodo más largo (16 semanas) se registró en la población de Donyina. Los datos de las tasas de crecimiento en la pre-estivación y la post-estivación muestran un orden decreciente: Apedwa > Nkasem > Donyina. Las tasas medias de crecimiento ocho semanas antes de la estivación eran 3,6 g, 14,3 g y 19,2 g para los caracoles de Donyina, Nkasem y Apedwa, respectivamente, y diferían significativamente (P = 0,001). La variabilidad en las tasas de crecimiento y la duración de la estivación reflejan los tamaños óptimos de las poblaciones naturales de los tres grupos.

Key words: The giant African Snail, *Achatina achatina*, aestivation, Ecotypes.
Palabras clave: Caracol gigante africano, *Achatina achatina*, estivación, ecotipos.

## INTRODUCTION

*Achatina achatina* (Linne, 1758) is found in the closed forest area in Ghana. It shows an annual activity which is maximal in the rainy season and minimal in the dry season. The snail burrows into the upper 10-15 cm

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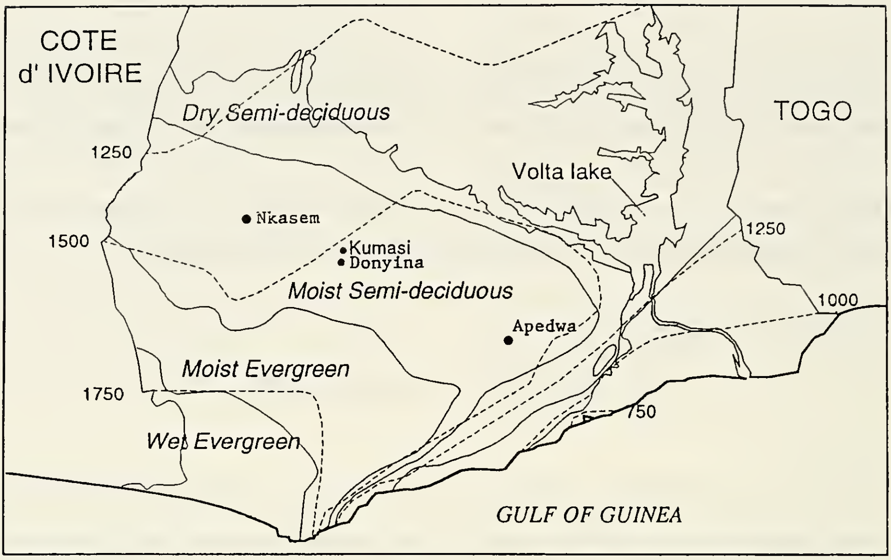


Figure 1. Map of the closed forest area of Ghana showing the trial site (Kumasi) and the origins (Donyina, Nkasem and Apedwa) of the snails used in trials.
*Figura 1. Mapa del área de bosque cerrado en Ghana mostrando el lugar del experimento (Kumasi) y los orígenes de los caracoles usados en el mismo (Donyina, Nkasem y Apedwa).*

of soil during the dry season and remains dormant for a period ranging from three to five months (COBBINAH, 1993). This state of dormancy during the dry season is referred to as aestivation. Circannual rythms are known to be induced by such factors as light, temperature, humidity and soil water deficit (OWEN, 1966). In the period leading to the onset of aestivation, there is a progressive decline in the snail's metabolism. BARATOU (1988) asserts that in order to maintain an equilibrium between water in its tissue and the relative humidity of the immediate environment, snails allow themselves to dehydrate during this period. For *Achachatina marginata* dehydration leads to the loss of about 42% liveweight of the non-shell tissues (STIEVENART, 1994). Later, a mucous layer is secreted to cover the shell opening; the fully formed mucous layer is impervious to both gases and water (HODASI, 1982). Snails go into a state of dormancy whenever conditions are too dry for their liking. Whilst this behaviour is most common in the dry seasons, COBBINAH (1993) reported that even dry spells during the wet seasons may induce aestivation in *A. achatina*.

This is, however, in contrast to the observation of HODASI (1982) that extensive and persistent dry conditions are necessary to induce aestivation, and that aestivation normally does not occur during the dry spells in the rainy season. Extremes of temperature and starvation is also reported to induce aestivation (KONDO, 1964).

HODASI (1982) suggested that not every individual in the population aestivates during the dry season. Accordingly in certain localities within the distribution range of *A. achatina* in Ghana, fresh snails can be obtained throughout the dry season. Here the results of studies undertaken to determine the variability in aestivation responses of populations from three distinct enclaves of *A. achatina* in Ghana is reported.

## MATERIALS AND METHODS

**Sources of Snails**: The snails for the study were obtained from (a) Donyina in the Ashanti Region, (b) Nkasem in the Brong Ahafo Region and (c) Apedwa in the Eastern Region. Donyina is 20 km from our test site on the campus of the University of Science and Technology, Kumasi, Ghana. Nkasem to the north west and Apedwa to the south east of Donyina are 109 and 198 km respectively from our test site. Figure 1 shows the origin of the three populations together with approximate isohyets. Donyina (6° 45′ N and 2°25′ W), Nkasem (6° 15′ N and 2° 20′ W) and Apedwa (6° 46′ N and 1° 25′ E) all fall within the rainfall regime 1250 mm-1750 mm typical of the moist semi-deciduous forest type. Seasonal rainfall at the three origins is influenced by meteorological Equator (ME). Two weather systems are associated with the ME, the Intertropical Front and the Intertropical Convergence Zone which cause short heavy rain storms and abundant continuous rain respectively and result in bimodal annual rainfall pattern with major rains falling between April-June and minor period of rains between September and October separated by two months of less frequent rains (LEROUX, 1988). The mean annual rainfall for the three locations are Donyina (1403 mm), Nkasem (1395 mm) and Apedwa (1561 mm). The main dry season falls between December and March. The soils at the three areas are of the forest ochrosols type. While all three areas fall within one forest vegetation type, different levels of logging and agricultural practices have resulted in varying rates of deforestation. The Donyina site has completely been converted into farmland over the years. The Apedwa site falls within the mountainous Atewa range protection forest reserve where timber exploitation is prohibited. However, pockets of illegal farms are not uncommon. The Nkesem site is an off reserve area with fairly dense vegetation interspersed with farmlands.

**Growth Rates**: The snails were conditioned in our research plot for four weeks on a diet consisting of pawpaw (*Carica papaya*) leaves and fruits, cocoyam (*Xanthosoma mofafa*) leaves, and leaves of the fameflower plant (*Talinum triangulare*). Individuals that showed signs of inactivity during this period were not used for the trials. Twenty snails of each group (ecotype) were placed in wooden boxes measuring 0.6 x 0.6 x 0.35 m, filled to a depth of 20 cm with sieved sterile silty sandy soil obtained from an abandoned rubbish dump. The snails in the boxes were offered excess amounts of food but left over foods were removed daily and soils overturned weekly. Because of high survival rates of *A. achatina* (COBBINAH AND OSEI-NKRUMAH, 1988) and insignificant changes in shell size over short periods of time, growth rates were measured by changes in live weights of snails. Each treatment was replicated three times, with data recorded for eight weeks prior to onset of aestivation and eight weeks after emergence from aestivation.

**Aestivation patterns of the three populations**: The aestivation patterns of individual snails used in the growth studies described above were monitored. Snails were considered as having aestivated when they covered the shell opening with a white mucous layer. Snails were recorded as emerged from aestivation when they discarded the epiphragm and resumed feeding.

A second trial was conducted to determine the effects of increased humidity. Each group of snails was divided into two lots. Twenty snails from one lot were placed in a 0.6 x 0.6 x 0.3 m wooden box as described above. A second set of 20 snails of the same ecotype was placed in another box with humidity slightly increased by making a platform about 15 cm above the soil level and placing a moistened fibre bag on the platform. The bag was kept moist for two weeks before onset of aestivation and throughout the aestivation period. Similar sets were set up for the other ecotypes and each treatment was replicated three times.

All snails used in the studies were labelled (paint marked) to enable observation of individual activities daily. Aestivation responses (time of onset and

Table I. Growth rates of three populations of *Achatina achatina* eight weeks before and after aestivation period.
*Tabla I. Tasas de crecimiento de las tres poblaciones de* Achatina achatina *ocho semanas antes y después del periodo de estivación.*

| Ecotype | Mean initial weight (g) ± s.e. | Mean weight gained in 8 weeks before aestivation ± s.e. | Mean weight gained in 8 weeks after aestivation ± s.e. |
|---|---|---|---|
| Donyina | 46.6+1.25 | $3.60+0.58^{a}$ | $10.83 + 0.17^{a}$ |
| Nkasem | 49.7+0.95 | $14.27+0.81^{b}$ | $12.47+ 0.35^{a}$ |
| Apedwa | 55 + 1.5 | $19.20+1.37^{c}$ | $19.58 + 2.87^{b}$ |

Means within a row followed by the same letter are not significantly different (P= 0.05).

emergence from aestivation) were recorded for all snails. The time required for 50% of each group to aestivate ($TEs_{50}$) or emerge from aestivation ($TEm_{50}$) was estimated for the various treatments and populations.

## RESULTS AND DISCUSSION

**Growth rates of the three populations**: The pre-aestivation growth rates for the Nkasem and Apedwa snails were four and five times more than that recorded for the Donyina snails. The mean growth rates 8 weeks before aestivation ranged from 3.6 g for Donyina to 19.2 g for Apedwa (Table I).

Analyses of the data (ANOVA) in Table I indicate that the growth rates among the three populations differed significantly for the pre-aestivation ($F = 83.94$; $df = 2, 6$; $P< 0.001$) and post-aestivation ($F = 7.73$, df 2, 6; $P< 0.02$) periods. However, Fisher's Multiple Range Test (LSD) did not show significant difference in the post-aestivation growth rates between the Donyina and Nkasem snails. The very low growth rates recorded for the Donyina group 8 weeks before aestivation suggest that, perhaps, aestivation in this group is preceded by significantly longer period of inactivity. Both the pre and post aestivation growth rates of the three populations indicate that the Apedwa group might be the most desirable group for commercial snail farming.

**Aestivation Patterns of the three Populations**: Figure 2A shows the aestivation pattern of the entire snail population. It took 10 weeks for all the snails in the test to aestivate. Three peaks are found in the second, sixth and tenth week. The three peaks show the heterogeneity in the response of the entire population to factors inducing aestivation.

Figure 2B shows the aestivation pattern of the Donyina ecotype. Aestivation commenced on 29 October 1993 and peaked on 6th November, 1993, one week after the beginning of aestivation. The entire Donyina group aestivated in 5 weeks. The first observation of aestivation for the Nkasem (Fig. 2C) and Apedwa (Fig. 2D) groups was recorded on 6th November, 1993 but peak aestivation for these two groups was recorded on 4th December, 1993 and 28th December, 1993, respectively. Aestivation for these two groups spanned a period of 8 and 9 weeks. Time taken for 50% of each population to aestivate ($TEs_{50}$) were 8, 28 and 52 days for Donyina, Nkasem and Apedwa snails respectively.

The relatively longer periods required for the Nkasem and Apedwa populations to complete aestivation is a reflection of the variability within these two populations. The peaks observed in Figures 2B-D corresponded to the peaks in Figure 2A and suggest that the heterogeneity in the aestivation pattern of *A. achatina* observed in our study was due mainly to the varia-

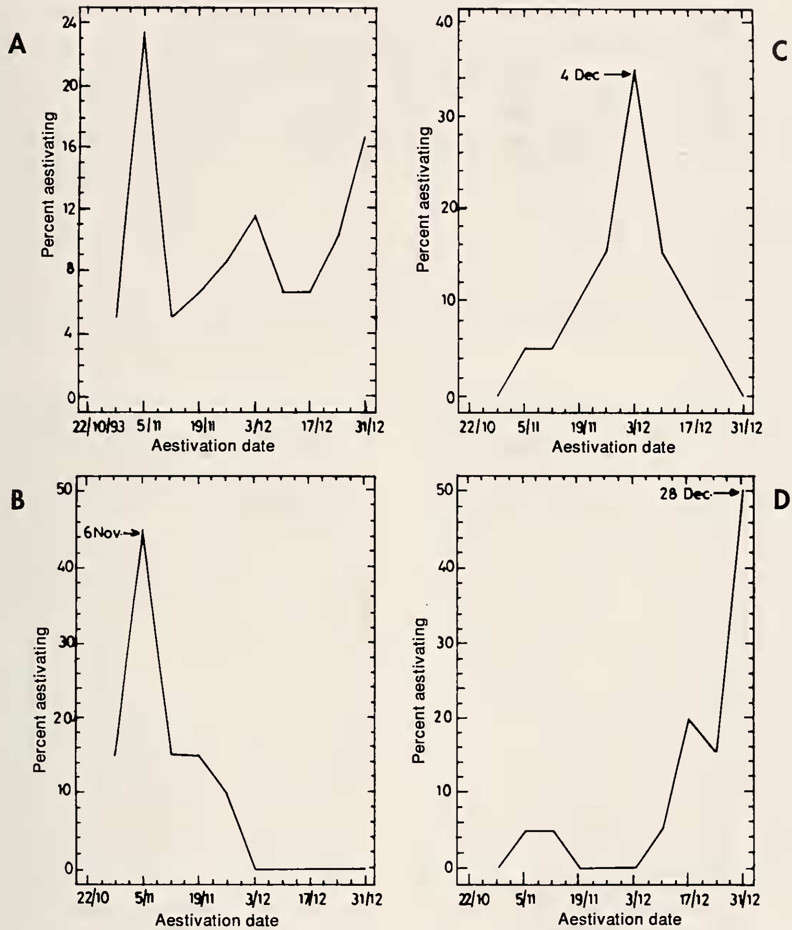


Figure 2. Aestivation patterns. A: entire experimental population; B: Donyina population; C: Nkasem population; D: Apedwa population.
*Figura 2. Patrones de estivación. A: toda la población experimental; B: población de Donyina; C: población de Nkasem; D: población de Apedwa.*

tion in the responses of the three groups to the factors inducing aestivation.

The emergence period for the entire population covered a period of 7 weeks from the end of January to mid-March, 1994. Again three peaks were evident (Fig. 3A). These were in the third, fifth and seventh week and corresponded to peak emergence periods for the Apedwa (Fig. 3D), Nkasem (Fig. 3C) and Donyina (Fig. 3B) respectively. The first snail to emerge from aestivation was from the Apedwa group on 31 January 1994 (Fig. 3D). By mid-February 60% of this group had emerged from aestivation. On the other hand, not a single snail from the Donyina group had emerged by mid-February, three and half months after initiation of aestivation (Fig. 3B). Twenty percent of the Nkasem group had resumed normal metabolic activities by mid-February (Fig. 3C). Peak emergence in the Donyina group was recorded during the first week in March. Time taken for 50% of population to emerge from aestivation ($TEm_{50}$) following the outset of emergence were 9,

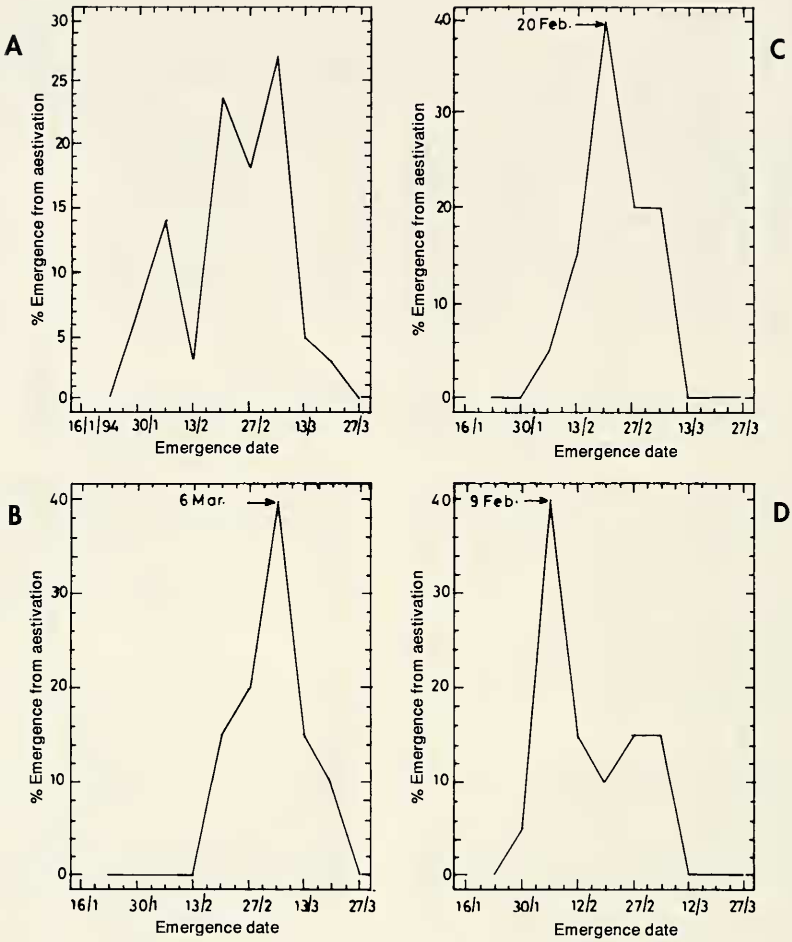


Figure 3. Emergence patterns. A: entire experimental population; B: Donyina population; C: Nkasem population; D: Apedwa population.

*Figure 3. Patrones de salida de la estivación. A: toda la población experimental; B: población de Donyina; C: población de Nkasem; D: población de Apedwa.*

20 and 33 days for Apedwa, Nkasem and Donyina groups respectively.

Humidity is considered a major factor affecting aestivation behaviour of *A achatina*. COBBINAH (1993) reported that when the relative humidity falls during the dry season *A. achatina* becomes inactive, seals itself in its shell with a white calcareous layer and aestivates in order to prevent loss of water from the body. In this study the enhanced humidity (3% above the ambient condition) attained in the boxes with moistened fibre bags did not influence the overall aestivation pattern of any of the three groups (see Table II).

Elmslie (pers. comm.) asserts that aestivation/hibernation may be influenced by a programmable regulation, resettable by environmental experience like circadian rhythm, but transmitted to offspring in the case of parents that have changed environment in a partially reset state. It is possible that the enhanced humidity in these boxes was not adequate to destabilise the in-built mechanism which sets in motion physiological

Table II. Aestivation patterns of snails in boxes with or without moistened fibre bags.
*Tabla II. Patrones de estivación de los caracoles en cajas con o sin bolsas de fibra humedecidas.*

| Ecotype | Mean Weekly Dry (68-70% rh) | % Aestivation Moist (68-74% rh) | Mean weekly Dry (57-62% hr) | % Emergence Moist (56-66% rh) |
|---|---|---|---|---|
| Donyina | 22.16 | 23.91 | 26.54 | 25.49 |
| Nkasem | 19.42 | 19.57 | 15.72 | 16.52 |
| Apedwa | 20 96 | 23.91 | 13.97 | 14.80 |

All differences are not significant at (P = 0.05).

changes resulting in aestivation during periods of low atmospheric humidity.

Whilst aestivation has adaptive value for the snail (HODASI, 1982; STIEVENART, 1994), for the snail farmer it represents the loss of valuable growing time. The three populations show significant differences in growth rates and duration of aestivation. Shorter aestivation period mean longer feeding period and ultimately larger body sizes.

Based on peak aestivation and emergence periods for the three groups, the estimated duration of the dormant periods were 4, 10 and 16 weeks for the Apedwa, Nkasem and Donyina respectively. Moreover, data on growth rates clearly show a decreasing order Apedwa > Nkasem > Donyina among the three groups during the pre and post aestivation periods. These two factors acting in concert may explain differences in adult sizes of *A. achatina* from various areas of the country. The Apedwa snails are usually twice the size of the Donyina snails (COBBINAH, 1993). The Nkasem snails are often intermediate in size between the two populations.

Although all the three enclaves where the snails originated from are within the moist semi-deciduous forest type and are characterized by similar soil type, there are differences in mean annual rainfall and vegetation cover. Soil water regime are influenced by rainfall gradient and evapotranspiration (VAN ROMPAEY, 1993). Most studies of the soil water regime in West African tropical forest (HUTTEL, 1975; COLLINET, MONTENEY AND POUYAUD, 1984) suggest that seasonal soil water deficits increase with decreasing annual rainfall. Mean annual rainfall is highest at Apedwa (1561 mm) but similar at Donyina (1403 mm) and Nkasem (1359 mm). In the three enclaves the Donyina area is the most degraded due to logging and slash and burn agriculture practices over the years. Unlike Apedwa and Nkasem where snails are mainly gathered from forest reserves and secondary forests outside reserves, the Donyina snails are mainly gathered from low vegetation farmlands. Although Donyina and Nkasem have similar mean annual rainfall, the relatively poor vegetation cover at Donyina would result in higher evapotranspiration and longer duration of seasonal drought. The snails from this area have probably adapted to this relatively long drought period through extension of dormancy period.

All individuals in the three groups aestivated in these studies. Nevertheless, a few individuals among the Apedwa group had shorter periods of aestivation than the four week group average. Further studies are, however, underway to determine whether some individuals or groups normally remain active throughout the dry season, and also to better understand the physiological, environmental and behavioural factors controlling aestivation. If the variability in the aestivation behaviour by the different individuals or groups has a significant genetic component, the resulting information would be of potential use for commercial snail farming.

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